

OBSERVATIONS ON THE INHERITANCE OF CHARACTERS
IN *ZEa MAYS* LINN.

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I.

SEGREGATION OF TWO PAIRS OF CHARACTERS IN A CROSS-BRED
MAIZE EAR.

The following statistical study of ear number 1157 has been made this season in the course of an investigation into the inheritance of characters in the maize plant (*Zea mays*). This ear was grown from a red flint grain of ear 1027; it has 12 rows of grain, which is red, white, or yellow in colour, and of the flint and sugar types. It was hand pollinated with pollen from other red-grain plants grown from ear 1027. The white grains are of a clear, pure white, without the least tendency to shade into red.

The following is a summary of the number of grains of each type in each row:—

TABLE 1.				TABLE 2.			TABLE 3.				
Row.	Red.	White.	Total.	Flint.	Sugar.	Total.	Red Flint.	White Flint.	Red Sugar.	White Sugar.	Total.
1	22	9	31	22	9	31	15	7	7	2	31
2	26	7	33	22	11	33	16	6	10	1	33
3	26	6	32	21	11	32	18	3	8	3	32
4	21	10	31	26	5	31	17	9	4	1	31
5	20	12	32	24	8	32	16	8	4	4	32
6	23	8	31	23	8	31	19	4	4	4	31
7	25	7	32	23	9	32	19	4	6	3	32
8	19	11	30	23	7	30	14	9	5	2	30
9	21	8	29	21	8	29	14	7	7	1	29
10	24	7	31	23	8	31	18	5	6	2	31
11	26	4	30	23	7	30	19	4	7	0	30
12	21	10	31	24	7	31	17	7	4	3	31
Total ...	274	99	373	275	98	373	202	73	72	26	373
Average per row }	23	8.25	31	23	8	31	17	6	6	2	31
Per cent.	73.45	26.55	—	73.73	26.27	—	54.16	19.57	19.30	6.97	—

Yellow colouring matter.—There are a few yellow grains on the ear, which are due to stray pollen from adjacent rows of yellow maize which have either mixed with the “red” pollen when the latter was being collected, or have gained access to the silks when the bag was removed for the purpose of hand-pollination. When the “yellow” pollen has fallen on to a “white” ovule it has produced a clear yellow grain; when it has reached a “red” ovule, the grain distinctly shows a mixture of red and yellow. There is thus no difficulty in distinguishing between red and non-red grains. Though not so pronounced in the sugar grains, the yellow colouring matter is quite distinguishable in contrast with the horny appearance of an ordinary “white” sugar grain.

Red colouring matter.—Table 1 shows clearly that in this case red is dominant over white. Where both red and yellow meet in the same grain, both colours appear (as is to be expected, red and yellow not being opposing characters), but the red is more conspicuous than the yellow; there is not any blending of colours such as occurs when blue and yellow meet in the same grain and produce green. The red colouring matter here discussed appears not to be confined to the pericarp, as is the case with the red colouring matter of “Red Cuzco” and some of the red strains frequently met with in fields of supposedly pure white maize; consequently it is transmitted differently. A separate experiment, also conducted this season, shows that the particular colour here dealt with is transmitted with the pollen, producing a red grain as the immediate result of the application of pollen of a red strain to the ovules of a white breed. There is considerable variation in the degree of redness in both dent and sugar grains, but there is no shading off into white such as is often the case with crosses between yellow and white.

Indentation.—The starchy (*i.e.*, non-sugary) grains are slightly indented; this was puzzling for a time, as the parent grains were red flints. Subsequently, however, one of the most vigorous plants in the row was found to have developed a red dent ear, and it is probable that the pollen from this plant caused the slight indentation in what would otherwise be flint grains.

Half-sugar Grain.—One grain is of particular interest because one half shows the sugar character and the other half the ordinary starch or “dent” character.

Percentages.—The percentages of each of the four types of grain obtained through the re-combination of the two pairs of characters, *i.e.*, redness and whiteness with dentness and sugariness, is interesting and instructive. The figures in Tables 1 and 2 show that both dentness and redness are dominant, while sugariness and whiteness are recessive.

The actual percentages occurring on this ear are summarised from Table 3 as follows:—

$$\begin{array}{l} \text{Red} \left\{ \begin{array}{l} \text{Dent} \dots\dots\dots 54.16\% \\ \text{Sugar} \dots\dots\dots 19.57 \end{array} \right\} = 73.73\% \\ \text{White} \left\{ \begin{array}{l} \text{Dent} \dots\dots\dots 19.30\% \\ \text{Sugar} \dots\dots\dots 6.97 \end{array} \right\} = 26.27\% \end{array} \left. \vphantom{\begin{array}{l} \text{Red} \\ \text{White} \end{array}} \right\} = 100\%$$

We should expect to find approximately the following proportions of each combination :—

	Red Grains.		White Grains.
Dent grains	75% of 75% = 56.25%	and	75% of 25% = 18.75%
Sugar grains	25% of 75% = 18.75%	and	25% of 25% = 6.25%

or—

$$\begin{array}{l} \text{Red} \left\{ \begin{array}{l} \text{Dent} \dots\dots\dots 56.25\% \\ \text{Sugar} \dots\dots\dots 18.75 \end{array} \right\} = 75\% \\ \text{White} \left\{ \begin{array}{l} \text{Dent} \dots\dots\dots 18.75\% \\ \text{Sugar} \dots\dots\dots 6.25 \end{array} \right\} = 25\% \end{array} \left. \vphantom{\begin{array}{l} \text{Red} \\ \text{White} \end{array}} \right\} = 100\%$$

For such a small total number of grains (373) the actual figures are remarkably close to the expected, and sufficiently so to be of practical use to the breeder.

II.

ROW-NUMBERS IN MAIZE EARS.

It is well known among maize-growers that the number of rows of grain on an ear of maize varies from 8 to 24 or even more, according to the breed; also that in the same breed the number may vary within certain limits, *e.g.*, 8, 10 or 12 in some breeds, 12, 14, 16 or 18 in others, and 18, 20, 22 or 24 in yet others. In some breeds the range of variation is even greater than this, while in others it seems to be more closely limited. In some breeds an ear carrying more than 8 rows is considered untrue to type, but I am not aware that any South African grower has yet succeeded in fixing the number of rows in any breed so that no variation occurs in that respect. In the course of a series of breeding experiments which are not yet complete, I have met with the following interesting case :—

Thirty-three plants of Arcadia sugar-maize each of which bore two well-developed ears, were studied as regards number of rows. On 21 plants the number on the upper ear was different from that on the lower, while on 12 plants the number was the same on each ear. Of the 21 plants of which the number of rows differed on the two ears, 13 had a larger number on the lower than on the upper, while 8 had a smaller number on the lower than on the upper. The distribution of rows was as follows :—

ARCADIA SUGAR-MAIZE.

Plants with 2 ears.

Plant No.	Upper Ear.	Lower Ear.
1	8	12
2	10	10
3	10	14
4	10	12
5	12	12
6	10	8
7	10	8
8	10	12
9	12	12
10	8	10
11	8	12
12	12	12
13	12	12
14	10	12
15	12	12
16	12	12
17	12	12
18	12	10
19	12	14
20	10	12
21	8	10
22	10	10
23	10	8
24	12	10
25	8	12
26	12	12
27	12	10
28	12	10
29	10	10
30	8	10
31	10	12
32 3 ears.	upper no grain.	middle 8
33	10	12

Class.	Upper Ear.	Lower Ear.	Number of Plants.	Number of Plants in each Class.
As many rows in lower as in upper	{ 12 10 8	{ 12 10 8	{ 8 3 1	12
More rows in lower than in upper ...	{ 10 10 8 8	{ 14 12 12 10	{ 1 6 3 3	13
Fewer rows in lower than in upper	{ 12 12 10	{ 14 10 8	{ 1 4 3	8

Summary.

Upper Ear.	Lower Ear.	Number of Plants.
8	{ 8	1
	{ 10	3
	{ 12	3
10	{ 8	3
	{ 10	3
	{ 12	6
	{ 14	1
12	{ 8	0
	{ 10	4
	{ 12	8
	{ 14	1
—	—	Total 33

The total number of ears producing any given number of rows is as follows :—

Rows.	Ears.
8	11
10	23
12	30
14	2
—	Total 66

The "Arcadia" is a white sugar-maize obtained as a cross between a normally 8-rowed "Black Mexican" and a white flour corn normally bearing a larger number of rows, but it is not known whether either was pure bred for row-numbers and no subsequent selection in this line has been made.

It is generally supposed by maize-growers, in this country at any rate, that the number of rows is a definite, heritable character. Results obtained by crossing two other breeds, viz., an 8-row and an 18-row (believed to be pure as regards this character) have this year produced intermediates in the F.1 generation. The case described above seems to indicate that the development of rows is within certain limits a vegetative character, depending in part on seasonal conditions and on food supply. This view is strengthened by the fact that this is the first year in which I

have noticed 14-row ears in this breed, all the parent ears for two or three generations having been 8-, 10-, or 12-rowed.

At the same time there is ample indication that within certain limits row-numbers are inherited in the maize plant, but it is doubtful whether any strains grown in South Africa are sufficiently pure bred for this character, to demonstrate the point with absolute certainty.

III.

INHERITANCE OF ROW-NUMBERS IN CROSS-BRED MAIZE.

The following is an advance note on the result of crossing an 8-rowed white dent maize ♀ (No. 904) with an 18-row yellow dent ♂ (No. 905) and of the reciprocal cross. Difficulty having been experienced in obtaining in South Africa any breeds of maize pure as regards row-numbers, I approached the United States Department of Agriculture, and with its kind assistance was enabled to obtain in 1909 what I required; both types bred true, and the cross and reciprocal cross were made in the season 1909-10.

White dent 8-row ♀ × Yellow dent 18-row ♂.—The ears produced as the direct result of cross-pollination bore all the visible characters of the mother plant, differing only in the cross-bred grain being yellow with a white cap.

Yellow dent 18-row ♀ × White dent 8-row ♂.—The ears produced as the direct result of cross-pollination bore the visible characters of the mother plant, differing only in the cross-bred grain having a white or light-yellow cap.

The F₁ generation.—The heterozygous grains obtained in 1909-10 were planted in the early part of the season 1910-11. Fifty-two plants were grown; these were carefully hand-pollinated with pollen from plants bearing the same record-number, *i.e.*, of the same parentage. The technique employed was to cover the ears with a loose paper bag, tied at the neck, as soon as the "silks" appeared. Pollen was collected by pulling the tassel, keeping the same overnight in a jug of water in a room free from draught, and during the succeeding three days collecting in a seed-envelope the pollen which fell on to a newspaper placed beneath for the purpose. To apply the pollen the bag was removed and sufficient pollen shaken on to the silks; the process was repeated twice, at intervals of seven to ten days, fresh pollen being collected for each operation. This usually resulted in the production of well-developed ears.

Thirteen plants were destroyed by stalk-borer, wind-storm or accident; leaving thirty-nine ears to be dealt with.

Explanation of Record-numbers.—The following record-numbers are used in the tables:—

1063 ex 905 (18-row ♀) × 904 (8-row ♂)	Yellow grain with light yellow caps.
1064 „ do. do.	Yellow grain with white caps.
1066 „ 904 (8-row ♀) × 905 (18-row ♂)	do.
1067 „ do. do.	do.
1068 „ do. do.	do.

Effect of Reciprocal Cross.—Separating the two crosses, we have the following figures :—

18-row ♀ × 8-row ♂.

Parent Ear No.	8.	10.	Rows. 12.	14.	16.	Total Ears.
1063	0	1	4	2	1	8
1064	0	2	4	0	0	6
Total.....	0	3	8	2	1	14
Per cent.	0	21.4	57.1	14.3	7.2	= 100

8-row ♀ × 18-row ♂.

Parent Ear No.	8.	10.	Rows. 12.	14.	16.	Total Ears.
1066	1	2	3	1	0	7
1067	0	2	4	3	0	9
1068	1	0	3	5	0	9
Total.....	2	4	10	9	0	25
Per cent.	8	16	40	36	0	100

Summary.

Parent Ear No.	8.	10.	Rows. 12.	14.	16.	Total Ears.
18 × 8	0	3	8	2	1	14
8 × 18	2	4	10	9	0	25
Total.....	2	7	18	11	1	39
Per cent.	5.1	18.1	46.2	28.2	2.6	100

Row-numbers as Fluctuating Variations.—The range of variation in the progeny, from 8 to 16 rows, is probably due in part to fluctuating variation such as is always met with in the maize plant, as for instance in the case of a 20-row ear produced by a pure-bred 18-row plant, and as in the case of plants which produce both 8-row and 10-row ears on the same plant. That this variation is partially dependent on conditions of growth is indicated by the frequent occurrence of ears bearing a pair of rows more in the lower half than in the upper; this seems to be especially prevalent in seasons which cause a check in growth. This season, which was dry during the early summer and wet towards the end, ears have been found with a pair of rows more in the upper part of the ear than in the lower. But the fluctuating variation in row-numbers appears to be limited, *e.g.*, an 8-row type shows fluctuating variation down to 4-rows on one side and up to 12-rows on the other side; I have met with a few cases of 14-row ears in a normally 8-row breed, but am inclined to think this may have been due to crossing. On the other hand, an 18-row breed may vary to 24-rows on one side and down to 14 on the other, but I doubt whether it ranges below 12.

Conclusions.—The cross between an 8-row and an 18-row breed results in the production of an intermediate form in the F.1 generation. Of the 39 cross-bred ears under consideration only two produced the same number of rows as either parent, while nearly 75 per cent. produced either 12 or 14 rows; as regards these two row-numbers, the cross and the reciprocal cross produced nearly the same proportions, the 18-row $\times$ 8-row giving 71.5 per cent., and the 8-row $\times$ 12-row 76 per cent.

It is intended to continue this investigation next year, and to record the splitting out in a large number of individuals, especially of the 10-, 12-, and 14-row ears.

IV.

NOTE ON INHERITANCE OF COB-COLOUR IN MAIZE.

A cross and reciprocal cross made between a white-cobbed, white-grained breed of maize (Hickory King) and a red-cobbed, yellow-grained breed has resulted in the production in the first filial generation of all red-cob ears. This experiment will be continued next year to determine the percentages of red and of white cobs which will reappear. This is of some importance to the maize-breeder, for red cobs are becoming too prevalent in white-grained breeds, to the detriment of the grain.

SUMMARY.

In "Red Cuzco" and some other breeds of red maize the red colouring matter is confined to the pericarp; being therefore a fruit character and not a seed character, it does not appear in the ear immediately resulting from a direct cross between a white ♀ and a red ♂.

In a red dent breed under investigation the red pigment occurs in the aleurone layer, and not in the pericarp. Being a seed character it is transmitted directly by the pollen grain to the ovule of a white breed. It behaves as a dominant to whiteness; where it meets yellowness in the same grain it is more conspicuous than yellow. The writer has not met with a previous record of the occurrence of a red pigment of this character in the aleurone layer of the maize grain.

When this red dent is crossed with a white sugar breed, the segregation in the second generation* of the two pairs of characters, redness *v.* whiteness and starchiness *v.* sugariness, is in approximately the following proportions:—

Red	{ Starchy	56.25	} = 75%
	{ Sugary	18.75	
White	{ Starchy	18.75	} = 25%
	{ Sugary	6.25	

In other words—

	Red Grains.	White Grains.
Starchy grains	75% of 75% = 56.25%	and of 25% = 18.75%
Sugary grains	25% of 75% = 18.75%	and of 25% = 6.25%
	75.00%	25.00%

A single grain has been found on the ear studied, which distinctly shows the starchy character in one half and the sugary character in the other—a very unusual feature.

A study of row-numbers in maize ears indicates that within certain limits the number of rows of grain on an ear is subject to fluctuating variation, which may perhaps be affected by season or food-supply, or both. In more than 20 plants of Arcadia Sugar-maize studied this year, each of which produced two ears on one stalk, the uppermost ear has had a different number of rows from that of the lower ear. On 13 plants the largest number of rows occurred on the lower ear, while on 8 plants the largest number was on the upper ear. In 12 plants of two ears the row-numbers were the same on both. In one case there were 4 more rows on one ear than on the other. Several plants of Hickory King bearing two ears, have also produced different numbers of rows on the two ears.

The range of variation appears to be limited, however; a normally 8-rowed type ranges between 4 and 14 rows, while a normally 18-rowed type ranges between 12 and 24 rows.

The result of crossing an 8-row with an 18-row type of maize is to produce an intermediate type in the first generation; both 8-row and 18-row types practically disappear in the heterozygous form. The intermediate type bears mostly 10, 12, or 14 rows, the 12-row type greatly predominating. The experiment will be continued next year to determine the proportion of the 8 row and 18-row types which reappear. The ears produced by the cross and the reciprocal cross are indistinguishable.

A white-cobbed breed crossed with a red-cobbed produces a red cob in the first filial generation, and so does the reciprocal cross.